THE ALIMENTARY CANAL OF *HARPALUS PENNSYLVANICUS* DEJ. (CARABIDAE: COLEOPTERA)

F. B. WHITTINGTON
Ohio State University, Columbus, Ohio

During the latter part of September, 1932, a species of Carabidae, *Harpalus pennsylvanicus* Dej., was found in large numbers about one mile west of Worthington, Ohio. The insect was most common under small batches of hay in an alfalfa field. About fifty specimens were collected and taken to the laboratory for use in a morphological study of the alimentary canal. Half of the specimens were immediately killed and fixed in Kahle's (Dietrich's) fixative. After thorough washing, these insects were then stored in 70 per cent alcohol for future use. The remaining twenty-five specimens were placed in a small screen cage about two feet square and covered with leaves at the base of a large sycamore tree. This procedure permitted the use of live specimens during the entire winter.

The figures herein presented were reproduced from material stained with Haemalum and Fast Green. This combination served very well to differentiate the cell layers and the nuclei, but in some sections the cell walls were not distinct. Delafield's haematoxylin and eosin were tried in various combinations but with results often less satisfactory.

This work was done at the Ohio State University under the supervision of Dr. Clarence H. Kennedy, to whom the writer is grateful for advice and criticism during the course of study.

GENERAL DESCRIPTION OF THE ADULT

The beetle is an oblong, robust species varying in length from 13–15.5 mm. The back is uniformly black and moderately shiny while the lower surface is dark reddish brown to piecious. The antennae are reddish yellow. The thorax is broader than long, with the base as wide as the elytra.

THE ALIMENTARY CANAL

The total length of the canal is approximately 21.5 mm. The cellular structure indicates that it is divided into three main divisions. The anterior portion, *fore-gut*, and the posterior portion, *hind-gut*, are continuations of the body wall. These two divisions are connected by a

central division, *mid-gut*, which is entirely different in cellular structure. The exact location of the main divisions and the subdivisions of the alimentary canal depends largely on the amount of food an individual has taken and the amount of adipose tissue in the body. In general, however, the fore-gut is approximately 8.5 mm. in length and occupies the position shown in Fig. 1, extending along the ventral part of the body to the first abdominal segment. The mid-gut, averaging 6.5 mm. in length, begins at the oesophageal valve and joins the hind-gut in the posterior half of the third abdominal segment. The hind-gut is approximately 6.5 mm. long, extending from the Malpighian tubules to the anal opening.

FORE-GUT

The fore-gut, measuring 8.5 mm., consists of the *buccal cavity*, *pharynx*, *oesophagus*, *crop*, *provintriculus*, and *oesophageal valve*. This division begins with the buccal cavity at the anterior end and extends to the oesophageal valve at the posterior end. The pharynx is very small and short, measuring less than .4 mm. in length. The oesophagus is approximately 4.5 mm. long, extending from the pharynx posteriorily to the crop. At this point the canal enlarges to form a bulb-like organ, the crop, which is about 3 mm. long and in most specimens occupies a position in the hind part of the metathorax and first abdominal segment. At the posterior end and somewhat from the side of the crop the provintriculus connects the crop to the mid-gut. The provintriculus is .5 mm. in length and is hardly distinguishable except by cellular structure.

In general the histological structure of the fore-gut is similar to that of the body wall. A cross-section of this part of the canal shows the following cellular layers: (1) a chitinous inner lining, *intima;* (2) an *epithelium* of hypodermal cells; (3) a layer of *longitudinal muscles;* (4) a layer of *circular muscles*, and (5) an inclosing membrane of *connective tissue* (*Peritoneum* with some writers). This arrangement of the cellular layers is continuous in the fore-gut, but in some sub-divisions a layer may be more pronounced than in others.

The intima or chitinous lining of the digestive cavity is distinct through the fore-gut. Figs. 2 and 5 show that in the oesophagus it is comparatively thin while in the provintriculus the layer is much heavier and is densely covered with spine-like projections. The large longitudinal folds are provided with secondary folds having serrated margins.

Epithelium is present in each of the subdivisions. In the oesophagus, however, the cells are hardly visible at a magnification of 440 times, while in the provintriculus they are outstanding under such magnification.

The longitudinal muscles of the fore-gut are in longitudinal folds which vary in number along the oesophagus. In the provintriculus they are definitely arranged into four distinct folds, the surface of which comprises approximately one-half the lining of the provintriculus.

The circular muscles vary from a few scattered strands around the walls of the oesophagus to a layer several cells in thickness in the provintriculus. The heavy layers of longitudinal and circular muscles in the provintriculus indicate that it is a powerful organ in the process of digestion even though it is relatively small.

A layer of connective tissue surrounds the fore-gut. In many cases this tissue is torn from the wall of the digestive tract in the process of sectioning.

The oesophageal valve, Fig. 6, marks the posterior end of the fore-gut. This valve consists of a heavy circular fold of the epithelium which extends slightly into the anterior end of the mid-gut. It is richly supplied with circular and longitudinal muscles, the position of which, in relation to the fore-gut, is completely reversed in this part of the canal.

MID–GUT

The mid-gut extends from the oesophageal valve at the anterior end to the pyloric valve at the posterior end. When in its natural position it is spiral shaped with the posterior end near the center of the body. It is approximately 6.5 mm. long and is divided into two slightly different parts, the *anterior mid-gut*, which is 1 mm. in length, and the *posterior mid-gut*, which measures 5.5 mm. This division of the canal is densely covered with *crypts* which are all uniformly perpendicular to the walls of the gut. Fig. 1 shows the uniformity which is expressed at the expense of the perpendicular arrangement. On the surface of the anterior mid-gut, the crypts are much larger than those on the posterior mid-gut.

There are four layers of cells in the mid-gut arranged in the following order, beginning with the lining of the digestive cavity (Fig. 4): (1) epithelial cells, (2) circular muscles, (3) longitudinal muscles, and (4) connective tissue. The epithelial layer is distinct and is locally crowded into folds between the bases of which it is evaginated into crypts that cover the surface of the mid-gut. This arrangement of cells greatly increases the surface of the epithelium in this division of the canal. The cells of this layer vary from a rectangular form in uncrowded conditions to a long club-shaped form where the cells are more congested.

Circular muscles of the mid-gut vary in thickness from one to three cells, and compared with circular muscles of other parts of the intestine, they are exceedingly minute.

The longitudinal muscles do not form a continuous layer around the mid-gut. Muscle strands that are present are often barely visible when magnified 950 times.

A thin layer of connective tissue surrounds the mid-gut (Fig. 4).

The crypts which cover the surface of the stomach are composed of large distinct cells which are continuous with the epithelium of the mid-gut. At the tip of the crypts are located the nidi which, according to Comstock, are areas of cell reproduction and rapid growth (Fig. 10).

HIND–GUT

The hind-gut is 6.5 mm. in length and consists of the *pyloric valve*, *Malpighian tubules*, *ileum* and *rectum*. The anterior end is marked by the entrance of the Malpighian tubules. The four tubules enter the digestive tract separately, but when viewed from the exterior they appear to enter in pairs. They are approximately the same length as the digestive tract and are thoroughly woven into the tracheae and

fatty tissue that surround the walls of the mid-gut. The ileum is 4.5 mm. in length and is comparatively uniform in size to a point near the junction of the rectum, where the size is doubled. The rectum is cone-shaped, tapering to about .3 mm. in diameter at the anal opening. The six rectal pads are located near the anterior end and are plainly visible through the transparent walls of the intestine (Fig. 1).

Beginning with the lining of the digestive cavity the cell layers appear in the following order: (1) intima, (2) epithelium, (3) longitudinal muscles, (4) circular muscles, (5) longitudinal muscles, and (6) connective tissue.

The pyloric valve is formed by a circular arrangement of enlarged areas of epithelium of the hind intestine (Figs. 7 and 8). Between these areas the malpighian tubules make their entrance to the digestive tract.

When viewed in cross-section the Malpighian tubules consist of a cellular layer varying from a large number of small cells at the open end to about ten large cells at a more distal point. The inner lining of the tubules is composed of *pore canals* which give this tissue a striated appearance when viewed in cross-section (Fig. 11). The large cells are surrounded by an inclosing layer of connective tissue which contains an occasional large cell which, it is believed, may serve as circular muscle.

The intima is evident throughout the hind intestine and is about equal in thickness in each subdivision.

The epithelium is continuous in the hind intestine. In the ileum it surrounds the large groups of longitudinal muscles. It varies in thickness along the tract, and in the rectal pads the layer is composed of two types of cells, the large rectangular cells of the pads and the normal epithelial cells at their base.

The longitudinal muscles are in two layers which are separated by circular muscles. The layer adjacent to the epithelium is grouped into six large folds of epithelial tissue. The second layer of longitudinal muscles is also in groups and is immediately surrounded by the connective tissue (Fig. 12).

The circular muscles are large and numerous in the ileum, while near the rectal pads the layer is reduced to scattered large cells.

The hind intestine is surrounded by a layer of very thin connective tissue (Figs. 7 and 12).

At the anterior end of the rectum the walls approach a transparent condition. As a result of this condition the rectal pads are subject to examination from the exterior. In an alternating arrangement three of these pads are more anteriorly placed than are the other three (Fig. 1).

BIBLIOGRAPHY

Comstock, J. H. An Introduction to Entomology, 1925.

Dufour, L. Recherches Anatomiques Sur les Carabiques et sur Plusicurs autres Insectes Coleopteres. Ann. Soc. Nat., Vol. 2, pp. 462–498. 1824.

Imms, A. D. A General Textbook of Entomology. E. P. Dutton and Co., Inc., N. Y. 1929.

Mansour, K. The Development of the Larval and Adult Mid-gut of *Calandra oryzae* Linn.: The Rice Weevil; Quart. Jour. Micr. Soc. (N. S.), 71, pp. 313–352. 1927.

Schaefer, P. E. The Alimentary Canal of *Sphaeroderus nitidicollis* Chev. var. schaumi Chd. (Coleoptera). Ohio Jour. Sc., Vol. 31, No. 5. 1931.

Woods, W. C. The Malpighian Vessels of *Haltica bimarginata* Say (Coleop.). Ann. Ent. Soc. Amer. 9, pp. 391–407. 1916.
Woods, W. C. The Alimentary Canal of the Larva of *Haltica bimarginata* Say (Coleop.). Ann. Ent. Soc. Amer., 11, pp. 283–318. 1918.

EXPLANATION OF PLATES

PLATE I

Fig. 1. Dorsal view of alimentary canal arranged to show the relative proportion and position of the parts. (× 10.)
Fig. 2. Cross-section of the oesophagus.
Fig. 3. A part of the same section as Fig. 2 when under much greater magnification.
Fig. 4. Cross-section of the posterior mid-gut. Note crowded condition of the epithelium and presence of folds.

PLATE II

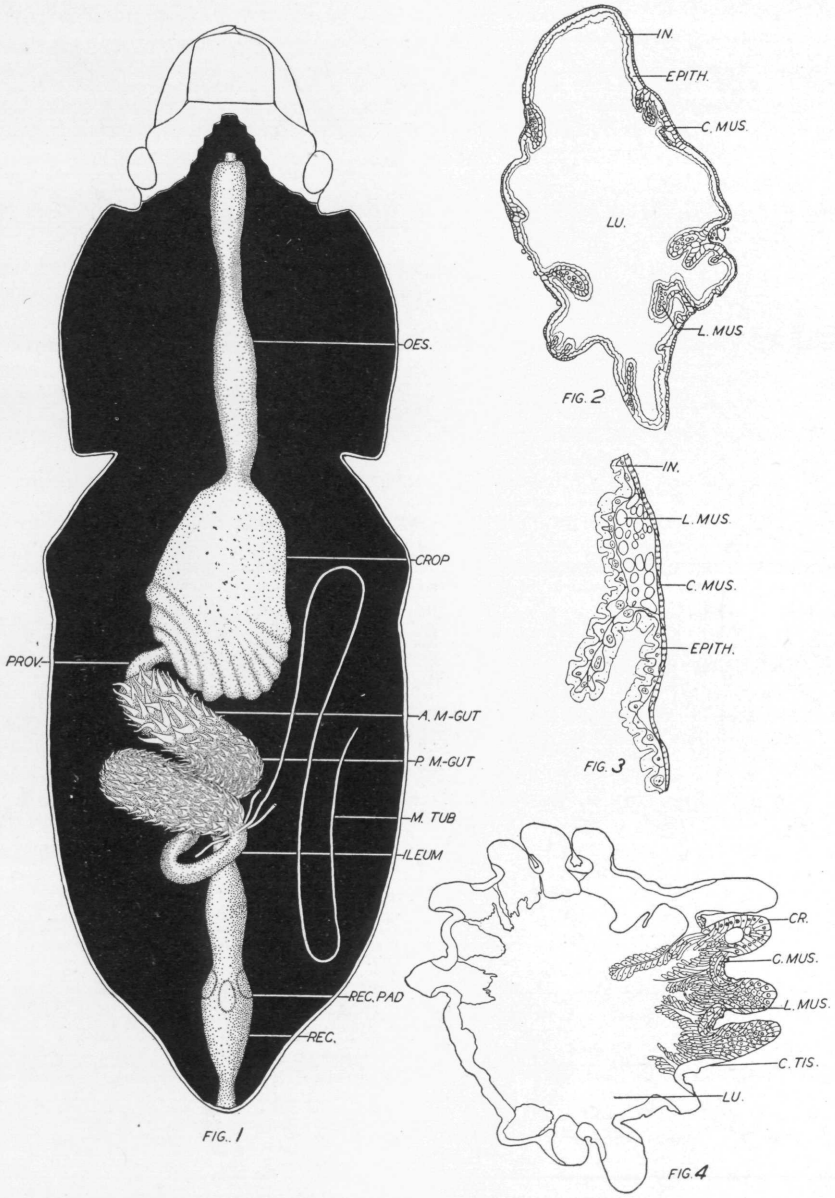
Fig. 5. Cross-section of the provintriculus. Note the heavy chitinous intima and spine-like projections.
Fig. 6. Longitudinal section of the provintriculus and oesophageal valve. Note change in position of muscle layers.
Fig. 7. Longitudinal section of the pyloric valve and part of ileum. Note change in position of muscle layers at valve. Two layers of longitudinal muscle are present in the ileum, but this section illustrates only one.
Fig. 8. Cross-section of the pyloric valve showing the entrance of the Malpighian tubules.

PLATE III

Fig. 9. Cross-section of the rectum showing the rectal pads.
Fig. 10. Longitudinal section of a crypt showing the nidus and globules of secretion.
Fig. 11. Cross-section of the Malpighian tubule near distal end.
Fig. 12. Cross-section of the ileum. Note the heavy layer of circular muscles and the two layers of longitudinal muscles.

SYMBOLS USED IN PLATES

A. M.—Anterior mid-gut
C. M.—Circular muscle
CR.—Crypt
C. TIS.—Connective tissue
EPITH.—Epithelium
EPITH. C.—Epithelial cells
IN.—Intima
L. MUS.—Longitudinal muscle
LU.—Lumen of intestine
M. TUB.—Malpighian tubule
OES.—Oesophagus
O. V.—Oesophageal valve
PROV.—Provintriculus
P. M. GUT—Posterior mid-gut
P. CANAL—Pore canal
P. V.—Pyloric valve
REC.—Rectum
REC. PAD—Rectal pad
SEC.—Secretion of crypt


OES.
CROP
PROV.
A. M-GUT
P. M-GUT
M. TUB
ILEUM
REC. PAD
REC.
FIG. 1
IN.
EPITH.
C. MUS.
LU.
L. MUS
FIG. 2
IN.
L. MUS.
C. MUS.
EPITH.
FIG. 3
CR.
C. MUS.
L. MUS.
C. TIS.
LU.
FIG. 4

Harpalus pennsylvanicus Dej.
F. B. Whittington

PLATE II

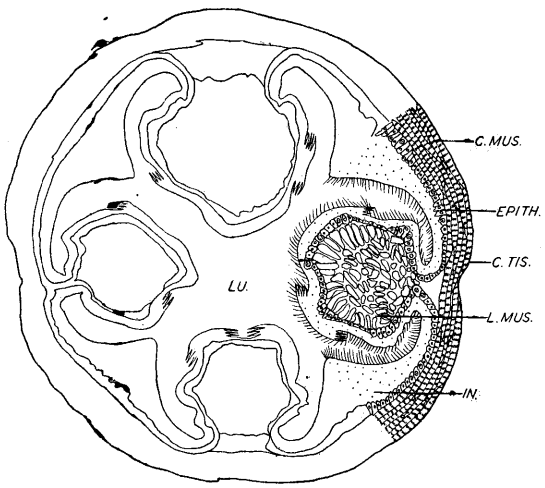


FIG. 5

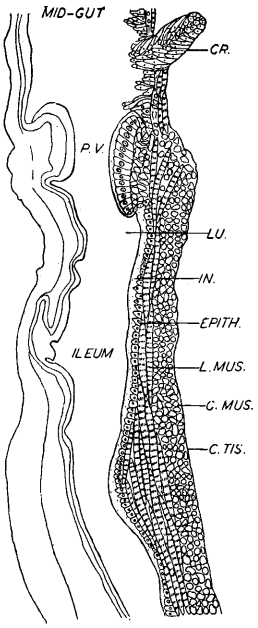


FIG. 7

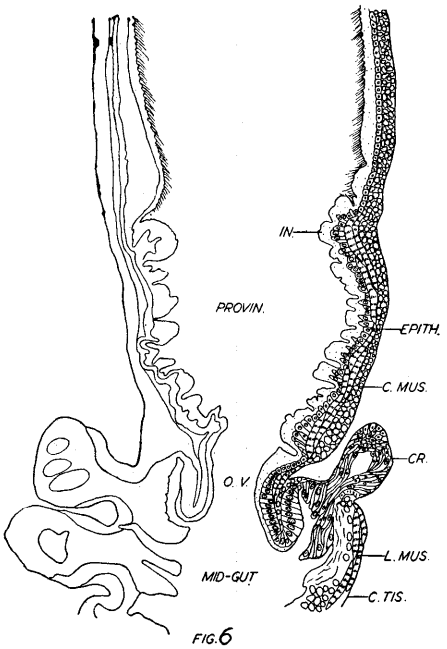


FIG. 6

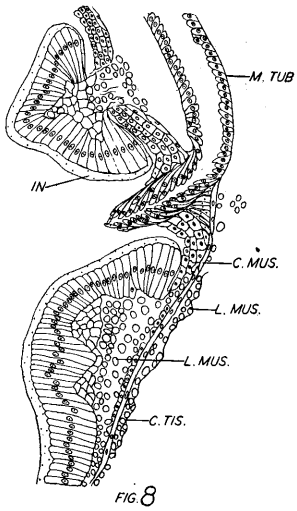


FIG. 8

Harpalus pennsylvanicus Dej.
F. B. Whittington

PLATE III

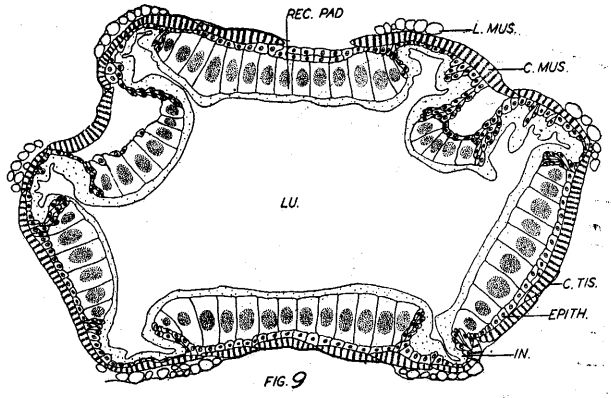


FIG. 9

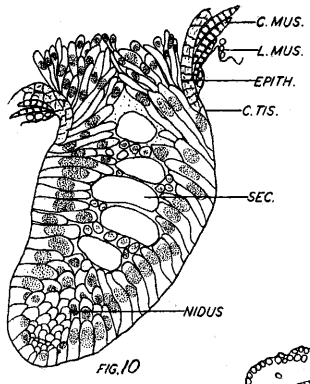


FIG. 10

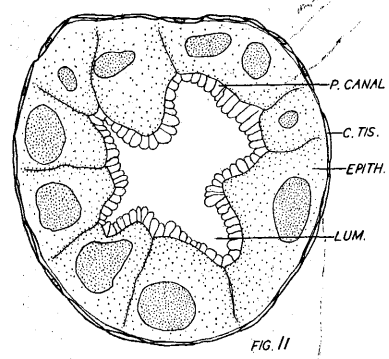


FIG. 11

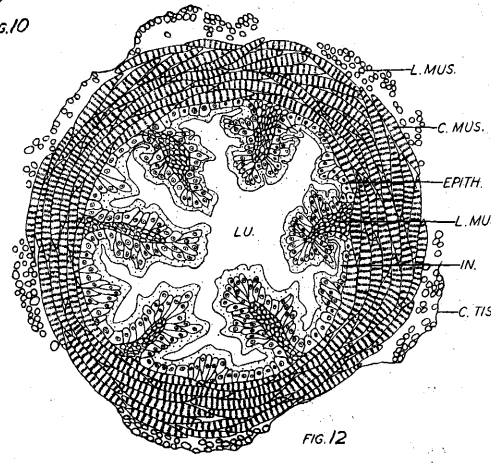


FIG. 12